

JOINT INVENTORS

**APPLICATION FOR
UNITED STATES LETTERS PATENT
SPECIFICATION**

TO ALL WHOM IT MAY CONCERN:

Be it known that we, Stephen E. O'ROURKE, a citizen of the United States of America, residing at 1847 Marne Road, Bolingbrook, Illinois 60490; Kimberly L. STEFANISIN, a citizen of the United States of America, residing at 4867 Wick Drive, Oak Lawn, Illinois 60453; and, Gary WENTWORTH, residing at 5540 North Wayne Avenue, Chicago, Illinois 60640, have invented a new and useful LOW POLARITY DIMERATE AND TRIMERATE ESTERS AS PLASTICIZERS FOR THERMOPLASTIC COMPOSITIONS, of which the following is a specification.

LOW POLARITY DIMERATE AND TRIMERATE ESTERS AS PLASTICIZERS FOR THERMOPLASTIC COMPOSITIONS

This claims the priority benefit under 35 U.S.C. §119(e) of U.S. provisional patent application serial no. 60/458,648, filed March 28, 2003, and U.S. provisional patent application serial no. 60/460,903, filed April 7, 2003, the entire disclosures of which are hereby incorporated herein by reference.

FIELD OF THE INVENTION

The invention is directed to low polarity dimerate and/or trimerate esters for plasticizing thermoplastic compositions containing one or more thermoplastic polymers.

BACKGROUND

A number of thermoplastic compositions are very difficult to plasticize. In particular, thermoplastic compositions, including polypropylenes, are difficult to plasticize because it is difficult to find plasticizers that are sufficiently compatible with thermoplastic compositions. Consequently, exuding (bleeding) of plasticizer to the surfaces of an article comprising a thermoplastic composition frequently occurs upon cooling and crystallization of the thermoplastic composition.

Hydrocarbon-based processing oils such as naphthenic oils or paraffinic oils have been used to plasticize thermoplastics such as polypropylenes. While hydrocarbon-based processing oils can be used to plasticize thermoplastics with partial success, the resulting plasticized compositions lack advantageous low temperature properties. Moreover, the processing oils have a tendency to exude (bleed) to the surfaces of thermoplastic articles. Attempts to use conventional linear dibasic acid esters, such as dioctyl adipate or di-2-ethylhexyl sebacate, or phthalate esters, such as di-2-ethylhexyl phthalate, have also been unsuccessful since such conventional ester plasticizers are either incompatible with thermoplastics, resulting in exudation of the plasticizer, or are too volatile for many thermoplastic uses.

U.S. Patent No. 5,290,886 teaches using organic ester plasticizers to plasticize thermoplastic elastomers comprising a blend of a thermoplastic polyolefin

and an elastomer to lower the glass transition temperature (T_g) of both the elastomer and the polyolefin phases and to improve impact strength at low temperatures. The '886 patent neither discloses nor suggests using the cyclic dimerate and/or cyclic trimerate esters disclosed herein, and found that "polymeric dibasic esters and aromatic esters were found to be significantly less effective" (column 3, lines 62-64)

Dimer acid esters have been proposed as plasticizers for high temperature resistant fluorocarbon polymers (see U.S. Patent No. 4,078,114) and for plasticizing anhydride-functionalized polymers (see U.S. Patent No. 5,169,716), but have not been suggested for plasticizing non-fluorocarbon polymers or non-anhydride-functionalized polymers. It is preferred that the thermoplastics plasticized with the dimerate and/or trimerate esters disclosed herein are not fluorocarbon polymers or anhydride-functionalized polymers.

Surprisingly and unexpectedly, particular dimerate and/or trimerate esters designed to have very low polarity act as efficient plasticizers for thermoplastics. The resulting plasticized compositions have excellent low temperature properties and exhibit little or no tendency of the plasticizer to exude or bleed to the surface of a thermoplastic composition. Using the low polarity dimerate and/or trimerate esters as a plasticizer provides an advantageous balance of flexibility, impact resistance, and strength to thermoplastic-containing compositions.

SUMMARY OF THE INVENTION

In brief, the use of long chain cyclic dimerate and/or trimerate ester plasticizers formed from mono-, di-, and/or tri-carboxylic acids, reacted with an alcohol containing a C₃-C₂₄ alkyl group, in one or more thermoplastics, unexpectedly improves the low temperature properties of the thermoplastic composition for uses in various molded and extruded products such as automobile bumpers, industrial and municipal pipe, outdoor patio furniture, appliance housings, and the like. Additionally, by adding one or more long chain cyclic dimerate and/or trimerate esters (di-, and/or tri-esters) in accordance with the disclosure to a thermoplastic composition, particularly dimerate esters formed by reacting the dimers and trimers of C₁₈ fatty acids with C₃-C₂₄ alcohols, preferably, C₃-C₁₈ alcohols, more preferably, C₆-

C₁₈ alcohols, the low temperature characteristics of the thermoplastic composition are surprisingly improved. Preferably, the long chain cyclic dimerate and/or trimerate ester plasticizers are formed by reacting a C₃-C₁₈ alcohol with a mixture of mono-, di, and tri-fatty acids, e.g., primarily C₁₈ carboxylic acids, and their dimers and trimers.

5 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

The cyclic dimerate and/or trimerate ester plasticizers described herein are added to a composition containing one or more thermoplastic polymers.

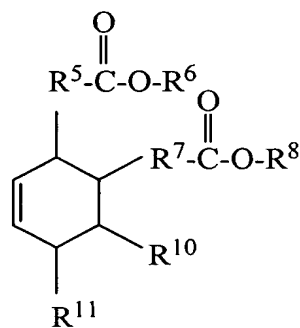
Surprisingly, the cyclic dimerate and trimerate ester plasticizers disclosed herein significantly increase the low temperature properties of the resulting plasticized,
10 thermoplastic composition and provide an excellent and unexpected balance of flexibility, impact resistance, and strength to the same.

The cyclic esters may be diesters (i.e., have two ester functionalities), triesters (i.e., have three ester functionalities), or mixtures thereof, that may include saturated or unsaturated hydrocarbon chains, straight chain or branched, having zero
15 to six double bonds in the hydrocarbon chains. While cyclic monoesters are less preferred, they also may successfully be used in accordance with the present disclosure.

Many of the cyclic diester and/or cyclic triester materials are formed from self reaction of naturally derived fatty acid mixtures containing oleic, linoleic,
20 and linolenic acids, and consequently are blends of mono-, di-, and tri-carboxylic acid esters. The ester blends may also include additional compounds that do not adversely affect the advantages imparted to a thermoplastic composition by the cyclic dimerate and/or trimerate esters described herein.

Ranges may be expressed herein as from "about" or "approximately"
25 one particular value and/or to "about" or "approximately" another particular value. When such a range is expressed, another embodiment includes from the one particular value and/or to the other particular value. Similarly, when values are expressed as approximations, by use of the antecedent "about," it will be understood that the particular value forms another embodiment.

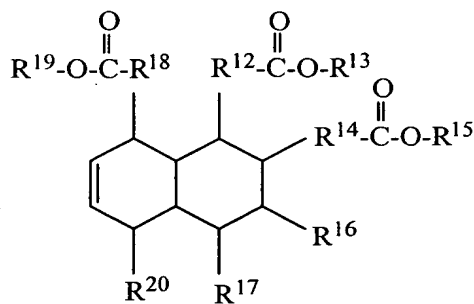
The cyclic diesters, referred to herein as dimerates, have a formula I, as follows:



(I)

- wherein R^5 and R^7 , same or different, are a C_3 - C_{24} , preferably C_6 - C_{24} , more preferably C_8 - C_{18} hydrocarbon chain, straight chain or branched, either saturated or containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds;
- R^6 and R^8 , same or different, are a C_3 - C_{24} alkyl, preferably C_3 - C_{18} alkyl, more preferably C_6 - C_{18} alkyl, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds; and
- R^{10} and R^{11} , same or different, are a C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} saturated hydrocarbon chain, straight chain or branched, or unsaturated C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} hydrocarbon chains, straight chain or branched, containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds.

The cyclic triesters, referred to herein as trimerates, have a formula II, as follows:



(II)

wherein R^{12} , R^{14} and R^{18} , same or different, are a C_3 - C_{24} , preferably C_6 - C_{24} , more preferably C_8 - C_{18} hydrocarbon chain, straight chain or branched, either saturated or containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds;

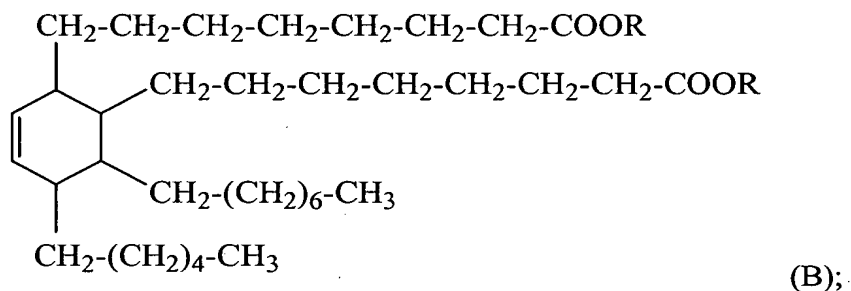
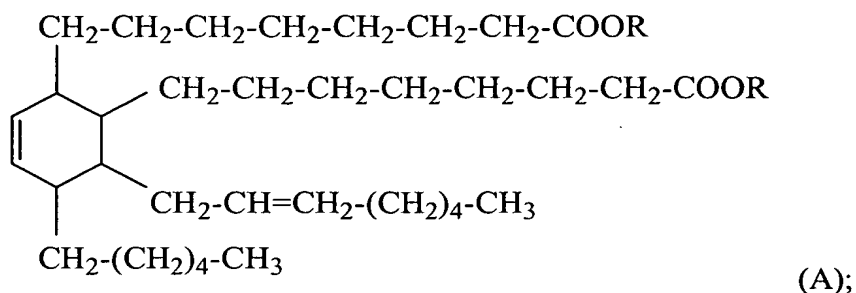
5 R^{13} , R^{15} and R^{19} , same or different, are a C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} alkyl, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds; and

R^{16} , R^{17} and R^{20} , same or different, are a saturated C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} hydrocarbon chain, straight chain or branched; or an unsaturated C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} hydrocarbon chain, straight chain or
10 branched, containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds.

The low polarity of the cyclic ester compounds disclosed herein is important for successfully plasticizing thermoplastic compositions. Low polarity cyclic ester compounds, e.g., ester compounds formed from dimer acids and alcohols having only acidic carboxyl groups are preferred (i.e., the dimer acids do not contain
15 other non-acidic hydroxyl substituents) and alcohols having a single hydroxyl group are therefore preferred for making same. Similarly, it is preferred that R^6 , R^8 , R^{13} , R^{15} , and R^{19} of formulas I and II do not contain hydroxyl substituents. Furthermore, dimerate esters formed from dimer acids and glycol type alcohols, for example, glycol alcohols such as ethylene glycol, diethylene glycol, triethylene glycol, and other
20 polyethylene glycols, would be too polar to plasticize thermoplastic compositions while simultaneously providing superior low temperature properties. Additionally, esters prepared by reacting dimer acids with the glycol functionalized monomers and oligomers set forth in U.S. Pat. No. 4,054,561 would also be too polar for use as plasticizers for thermoplastics.

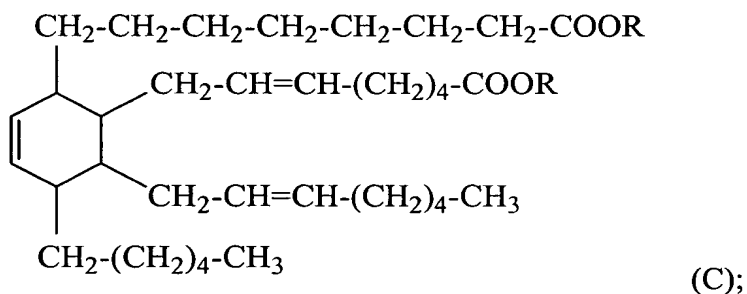
25 Useful cyclic diesters falling within formula I include dimerate ester structures formed by the reaction of a C_{36} dimer acid derived from tall oil fatty acids and a C_3 - C_{24} , preferably C_3 - C_{18} , more preferably C_6 - C_{18} alcohol, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds. Examples of such cyclic esters include the following structures, wherein the dimer
30 acid corresponding to structure A is formed by self reaction of linoleic acid, the dimer acid corresponding to structure B is formed by reacting linoleic acid with oleic acid,

and the dimer acid corresponding to structure C is formed by reacting linoleic acid with linolenic acid:



5

and

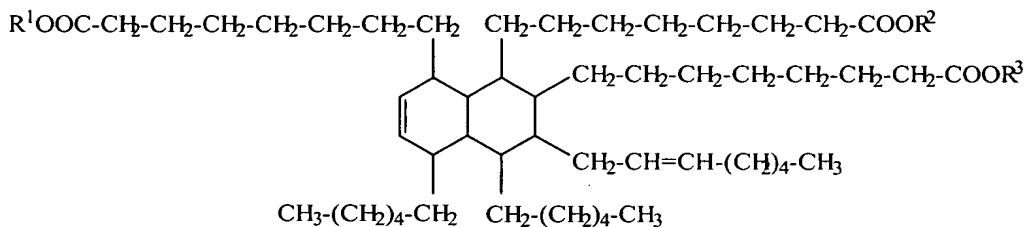


10 wherein each R, same or different, in formulas (A), (B), and (C) is a C₃-C₂₄ radical, preferably C₃-C₁₈, more preferably C₆-C₁₈, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds.

RX-13804, RX-13824, and RX-13892 are additional examples of dimerate esters in accordance with formula I. RX-13804 is formed by the reaction of a predominantly C₃₆ dimer acid with 2-ethylhexyl alcohol. RX-13824 is formed by

the reaction of a predominantly C₃₆ dimer acid with tridecyl alcohol. RX-13892 is formed by the reaction of a predominantly C₃₆ dimer acid with oleyl alcohol.

A representative example of a triester (trimerate ester) in accordance with formula II is the following structure (D):



5

(D);

wherein each R¹, R², and R³, same or different, is a C₃-C₂₄ radical, preferably C₃-C₁₈, more preferably C₆-C₁₈, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds.

10

Throughout the specification, the term dimerate is sometimes used when referring to mixtures of structures in accordance with both formulas I and II (i.e., dimerates and trimerates).

15

The cyclic ester plasticizers of formula I, II, or mixtures thereof are typically added to a thermoplastic composition comprising one or more thermoplastic polymers in an amount of about 0.1 parts to about 40 parts by weight, preferably from about 0.5 parts to about 20 parts, more preferably from about 3 parts to about 15 parts per 100 parts by weight of the thermoplastic polymer(s) in the thermoplastic composition.

20

A particularly useful blend of carboxylic acids for forming cyclic esters in accordance with the disclosure is a blend of carboxylic acids known as dimer acid having CAS#: 61788-89-4, which is a blend including primarily, C₃₆ and C₅₄ dimer and trimer acids, and predominantly (more than 50% by weight) C₃₆ dimer acid.

25

The fatty acid residues or hydrocarbon chains R⁵, R⁷, R¹², R¹⁴ and R¹⁸ of the esters of formulas I and II can be any C₃-C₂₄, preferably C₆-C₂₄, more

preferably C₈-C₁₈ hydrocarbon chain, either saturated or containing 1 to 6, preferably 1 to 3, carbon-to-carbon double bonds. The fatty acids can be derived from animal or vegetable fatty acids such as butter; lard; tallow; grease; herring; menhaden; pilchard; sardine; babassu; castor; coconut; corn; cottonseed; jojoba; linseed; oiticica; olive; palm; palm kernel; peanut; rapeseed; safflower; soya; sunflower; tall; and/or tung. Examples are the hydrocarbon chain residues from the following fatty acids, where the number in parentheses indicates the number of carbon atoms, and the number of double bonds, e.g., (C₂₄₋₆) indicates a hydrocarbon chain having 24 carbon atoms and 6 double bonds: hexanoic (C₆₋₀); octanoic (C₈₋₀); decanoic (C₁₀₋₀); dodecanoic (C₁₂₋₀); 9- dodecenoic (CIS) (C₁₂₋₁); tetradecanoic (C₁₄₋₀); 9-tetradecenoic (CIS) (C₁₄₋₁); hexadecanoic (CIS) (C₁₆₋₀); 9-hexadecenoic (CIS) (C₁₆₋₁); octadecanoic (C₁₈₋₀); 9-octadecenoic (CIS) (C₁₈₋₁); 9,12-octadecadienoic (CIS, CIS) (C₁₈₋₂); 9, 12, 15-octadecatrienoic (CIS, CIS, CIS) (C₁₈₋₃); 9, 11, 13-octadecatrienoic (CIS, TRANS, TRANS) (C₁₈₋₃); octadecatetraenoic (C₁₈₋₄); eicosanoic (C₂₀); 11-eicosenoic (CIS) (C₂₀₋₁); eicosadienoic (C₂₀₋₂); eicosatrienoic (C₂₀₋₃); 5, 8, 11, 14-eicosatetraenoic (C₂₀₋₄); eicosapentaenoic (C₂₀₋₅); docosanoic (C₂₂); 13-docosenoic (CIS) (C₂₂₋₁); docosatetraenoic (C₂₂₋₄); 4, 8, 12, 15, 19-docosapentaenoic (C₂₂₋₅); docosaheptaenoic (C₂₂₋₆); tetracosenoic (C₂₄₋₁); and 4, 8, 12, 15, 18, 21-tetracosahexaenoic (C₂₄₋₆).

Commercially available blends of useful polybasic acids that can be reacted with C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ alcohols, straight chain or branched, saturated or unsaturated containing 1 to 3 carbon-to-carbon double bonds to produce the dimerate and trimerate esters as blends, include the following: EMPOL® 1010 Dimer Acid; EMPOL® 1014 Dimer Acid; EMPOL® 1016 Dimer Acid; EMPOL® 1018 Dimer Acid; EMPOL® 1022 Dimer Acid; EMPOL® 1024 Dimer Acid; EMPOL® 1040 Trimer Acid; EMPOL® 1041 Trimer Acid; EMPOL® 1052 Polybasic Acid; and similar PRIPOL™ products from Uniqema as well as UNIDYME® products from Arizona Chemical.

Particularly useful ester additives are made by reacting any of the long chain mono, dimer and/or trimer acids with one or more straight chain or branched C₃-C₂₄, preferably C₃-C₁₈, more preferably C₆-C₁₈ alcohols to produce esters in accordance with formulas I and II.

The above dimer, trimer, and polybasic acids are produced by dimerizing, trimerizing, and polymerizing (oligomerizing) carboxylic acids, typically C_{18} fatty acids. The C_{18} fatty acids are typically mixtures. For example, the dimer acid produced from a C_{18} carboxylic acids (e.g., a mixture of stearic, oleic, linoleic, and linolenic) will result in a blend of numerous cyclic dimerate and trimerate esters, as in formulas I and II, some saturated and some containing hydrocarbon chains having 1 to 6, generally 1 to 3, carbon-to-carbon double bonds. Any one, or any blend, of the esters that include the cyclic dimerate and/or cyclic trimerate esters in accordance with formulas I or II will function to plasticize thermoplastics, and provide a balance of flexibility, strength, and low temperature properties, with essentially no bleeding of the plasticizer to the surface of the thermoplastic articles. Particularly, the plasticized thermoplastic compositions described herein are characterized in that the low temperature properties are improved to provide a balance of good flexibility and strength at low temperatures.

As used herein, thermoplastics generally include synthetic high polymers that soften when exposed to heat and return to their original state when cooled to room temperature. More specifically, thermoplastics that can be successfully plasticized using the long chain ester plasticizers described herein include polyvinyl chlorides, nylons, propylene/ α -olefin copolymers, ethylene/ α -olefin copolymers such as, for example, ethylene/propylene copolymers and ethylene/1-octene copolymers, polyolefins such as polyethylenes and polypropylenes, polystyrenes such as styrene/ethylene block copolymers and hydrogenated styrene/butadiene block copolymers, acrylic resins, and combinations thereof.

Preferably, the plasticizers described herein plasticize thermoplastics such as polypropylenes, propylene/ α -olefin copolymers, ethylene/ α -olefin copolymers, block copolymers of styrene with ethylene, hydrogenated styrene/butadiene block copolymers, and combinations thereof. Most preferably, the plasticizers described herein plasticize ethylene/1-octene copolymers and polypropylene blended with ethylene/propylene copolymers.

The plasticizers described herein are particularly preferred for plasticizing polypropylenes. Commodity grades of polypropylenes typically have a

high degree of crystallinity. Objects made from such commodity grades typically lack flexibility and can be somewhat brittle, especially at low temperature. The addition of one or more of the long chain cyclic ester plasticizers disclosed herein gives such grades of polypropylenes a highly desirable balance of flexibility, impact
5 resistance, and strength.

The invention may be better understood by reference to the following examples in which parts and percentages are by weight unless otherwise indicated.

As shown in the examples, thermoplastics plasticized with dimerates exhibit lower weight losses when compared with conventional dibasic esters, and
10 reduced melt torque and improved low temperature properties when compared with paraffinic oils.

In the following examples, cyclic dimerate esters and conventional plasticizers such as tridecyl tallate, dioctyl sebacate, and paraffinic oil were applied to two different polypropylene samples. The two polypropylene samples differ in
15 molecular weight and melt flow rate. As used herein, melt flow or melt index values indicate the amount of plastic that can extruded in ten minutes through an opening under a prescribed load. The 1012 polymer is a higher molecular weight polymer which has a lesser melt flow rate (1.2 grams vs. 20 grams) than the 1246 polymer. Both the 1012 and 1246 polymers are commodity grade polypropylenes.

20 Tables I and II include data relating to the original physical properties, such as stress, strain, and fusion torque, of polypropylene samples plasticized with plasticizers in accordance with the disclosure. Fusion characteristics were measured using a Polylab System® torque rheometer from Thermo Haake using a Rheomix® 600 mixing head. Conditions for mixing measurements generally were about 170°C-
25 200°C/77 rpm.

As shown therein, thermoplastic olefins plasticized with dimerates exhibit lower weight losses upon heat aging, as compared to conventional dibasic esters, and reduced melt torque and improved low temperature properties when compared to paraffinic oils. These attributes are especially important in applications

such as automotive interior, film packaging, low temperature impact resistance, and other applications requiring improved processing and flexibility.

Results

5 The processing properties of polypropylene plasticized with dimerate esters show results which are equal to (if not better than) those achieved with the use of conventional plasticizer compounds. For example, the air oven aging data of Table I shows that dimerate plasticizers (examples 2-4) are less volatile when compared with conventional linear dibasic acid ester compounds such as DOS (example 5) and tridecyl tallate (example 1). Further, when compared with paraffinic oil (example 6),
10 the addition of dimerate plasticizers to the polypropylene sample substantially reduces melt torque.

 Glass transition data also indicate that dimerate plasticizers effectively plasticize thermoplastic compositions. For example, as shown in Table 1, examples 2 and 3 (containing dimerate plasticizer compounds in accordance with the disclosure)
15 had lower glass transition temperatures (i.e., possess superior low temperature properties) than examples 5 (containing DOS) and 6 (containing paraffinic oil).

Table I

Example	1	2	3	4	5	6	7
Homopolymer 1246 Injection Molding Resin	100.0						→
TE-577	10.0	---	---	---	---	---	---
RX-13804	---	10.0	---	---	---	---	---
RX-13824	---	---	10.0	---	---	---	---
RX-13892	---	---	---	10.0	---	---	---
Plasthall® DOS	---	---	---	---	10.0	---	---
Sunpar 2280	---	---	---	---	---	10.0	---
Total	110.0	110.0	110.0	110.0	110.0	110.0	100.0
Major Variable	TE-577	RX-13804	RX-13824	RX-13892	Plasthall DOS	Sunpar 2280	Unplast
Original Physical Properties							
Stress @ Peak, MPa	25.4	26.4	25.9	25.1	28.3	25.6	37.9
psi	3685	3825	3765	3640	4105	3710	5495
Strain @ Break, %	4	2	9	5	6	8	5
Hardness Duro D, pts.	69	66	67	66	65	67	73
Specific Gravity	0.900	0.901	0.886	0.890	0.907	0.894	0.905
Tg-°C	0	5	5	7	12	8	15
Rheomix 600 77 RPM, 170°C							
Fusion Torque, mg	805	1100	1200	1090.8	1000	917.7	2258.1
Fusion Temperature, °C	151	154	154	154	152	155	157
Melt Temperature, °C	194	174	175	174	174	176	176
Melt Torque, mg	88.8	186.0	181.4	178.5	153.0	215.0	350.0
Energy, kJ	9.0	17.5	18.0	17.5	15.0	19.0	34.5
Air Oven Aging, 3 days @ 125°C							
Tensile Ultimate @ Break, MPa	21.6	25.2	25.3	24.3	30.5	25.3	40.1
psi	3135	3660	3665	3525	4420	3675	5815
Tensile Change, %	-15	-4	-3	-3	8	-1	6
Elongation @ Break, %	2.5	4.9	9.6	12.1	1.3	6.5	6.4
Elongation Change, %	-38	145	7	142	-78	-19	28
Hardness, Duro D, pts.	67	69	69	69	71	69	71
Hardness Change, pts.	-2	3	2	3	6	2	-2
Weight Change, %	-4.4	-0.7	-0.7	-0.6	-8.1	-0.8	-0.6

Results

The processing properties of polypropylene plasticized with dimerate esters show results which are as good as (if not better) than achieved with the use of conventional plasticizer compounds. For example, the air oven aging data of Table II shows that dimerate plasticizers (examples 9-11) are less volatile when compared with conventional linear dibasic acid ester compounds such as DOS (example 12) and tridecyl tallate (example 8). The air oven aging results show that the dimerates are essentially equal to the paraffinic oil in weight loss, which is a significant improvement over conventional organic ester plasticizers and tallate compounds. Further, when compared with paraffinic oil (example 13), the addition of dimerate plasticizers to the polypropylene sample substantially reduces melt torque. Therefore, the long chain cyclic ester plasticizers described herein provide superior processing properties with respect to such conventional plasticizing agents.

Table II

Example	8	9	10	11	12	13	14
Homopolymer 1012 Fiber Resin	100.00	---	---	---	---	---	---
TE-577	10.0	---	---	---	---	---	---
RX-13804	---	10.0	---	---	---	---	---
RX-13824	---	---	10.0	---	---	---	---
RX-13892	---	---	---	10.0	---	---	---
Plasthall® DOS	---	---	---	---	10.0	---	---
Sunpar 2280	---	---	---	---	---	10.0	---
Total	110.0	110.0	110.0	110.0	110.0	110.0	100.0
Major Variable	TE-577	RX-13804	RX-13824	RX-13892	Plasthall DOS	Sunpar 2280	Unplast
Original Physical Properties							
Stress @ Peak, MPa	28.4	29.3	29.5	27.8	28.5	29.6	37.3
psi	4120	4255	4275	4036.5	4130	4295	5405
Strain @ Break, %	18.6	29.1	48.7	19.4	31.8	78.2	17
Hardness Duro D, pts.	66	67	65	67	67	69	75
Specific Gravity	0.902	0.918	0.886	0.883	0.891	0.857	0.874
Rheomix 600 77 RPM, 200°C							
Fusion Torque, mg	1750	1892	1639	1660	1711	1847.5	2475
Fusion Temperature, °C	165	167	167	167	165	171	186
Melt Temperature, °C	207	207	207	207	208	209	211
Melt Torque, mg	344	471	456	470	550	528	781
Energy, kJ	27	33	31	31	35	33	46
Air Oven Aging, 3 days @ 125°C							
Tensile Ultimate @ Break, MPa	*TB	4.1	2.1	4.0	22.5	28.9	35.8
psi		590	305	585	3265	4185	5190
Tensile Change, %		-86	-93	-86	-21	-3	-4
Elongation @ Break, %		0	0	0	9	100	24
Elongation Change, %		-100	-100	-100	-72	28	41
Hardness Duro A, pts.		70	69	66	71	65	75
Hardness Change, pts.		3	4	-1	4	-4	0
Weight Change, %		-0.5	-2.1	-1.7	-6.8	-1.2	0.0
*TB - too brittle to test							

Material List for Tables I & II

5

Material	Chemical Description	Supplier
Homopolymer 1012 Fiber Resin	polypropylene homopolymer MFR 1.2	BP Amoco
Homopolymer 1246 Injection Molding Resin	polypropylene homopolymer MFR 20	BP Amoco
Hallco TE-577	Tridecyl Tallate	The C. P. Hall Company
RX-13804	Di(2-ethylhexyl) dimerate	The C. P. Hall Company
RX-13824	Di(tridecyl) dimerate	The C. P. Hall Company
RX-13892	Di(oleyl) dimerate	The C. P. Hall Company
Plasthall DOS	Dioctyl Sebacate	The C. P. Hall Company
Sunpar 2280	Paraffinic Oil	Sun Chemical